

**Topics for Technical Meeting Concerning the
Site Specific Probable Maximum Precipitation (PMP)
for the Cherry Creek Drainage in Colorado**

1. Original analysis of 1935 storm (Cherry Creek & Hale) cannot be easily challenged with the available data, but there are concerns about the depth and areas associated with that storm and the impact they have on later Colorado PMP assumptions. (Doesken)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

2. Primary overall concern with this PMP is the “storm area” and, to a lesser extent the storm centering in light of the southeasterly surface winds needed to advect the quantity of moisture associated with such an extreme storm. (Doesken)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

3. Have no problem with the depth of rainfall associated with the PMP storm, but troubled by the areas assumed – and these have HUGE impacts on the subsequent results. Appreciate a conservative approach, but this seems excessively conservative especially when compared to any known storm anywhere along the Rocky Mountain front from northern New Mexico to Montana. Physically, how could such large areas be affected, with a north-south orientation, on the downwind (under most likely extreme precipitation scenarios) side of a significant topographic barrier. (Doesken)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

4. The March 5, 1999, “peer” review response submitted by the United States Army Corps of Engineers is simply another in-house review prepared by the National Weather Service, is not an independent analysis, and does not address the full range of issues that are typically addressed in a proper independent peer review. (Colorado Senate Joint Resolution 99-023)

The group consensus was that the review performed in March 1999 was a ~~proper and~~¹ independent review.

5. Since the western limit for the application of HMR 52 has varied from publication to publication, what is the current western limit and how was it derived? (Tomlinson)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

6. HMR 52 was not developed using storms considered transpositionable to the Cherry

¹ Deleted as per request from Dr. Edward Tomlinson during public meeting held on July 22, 1999.

Creek drainage basin. What analysis (i.e. analysis vs opinion) has been performed to demonstrate the HMR 52 is appropriate for use for the non-orographic component of PMP for the Cherry Creek location? (Tomlinson)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

7. The most recent storm included in HMR 55A analyses is 1978. Was a review of more recent storms conducted to identify significant rainfall events which could influence the site-specific PMP study? (Tomlinson)

The NWS reviews storm events after they occur to determine if an event would have a significant impact on the regional study. As of 1995, no storms were identified that would alter HMR 55A.

8. Table 14 in HMR 52 provides a list of the storms used to develop the within/without curves. Averages of values from these 29 storms were used and smoothed. It is stated that the authors of HMR 52 chose not to consider any regional variation that may exist in these storm ratios. They additionally state that they consider this conclusion (i.e. not to consider regional variations) to be justified at this time (1982) but add “¼, however, future study should investigate regional variation in depth-area relations.” In the HMR 55A discussions related to Depth-Area-Duration Relations (Section 11), it states that “¼DAD relationships in the non-orographic regions west of the HMR No. 51 region should decrease with increasing area size at an even faster rate than they do within the HMR No. 51 region.” In light of these identified variations west of the HMR 51 region and the suggestion that future studies should investigate regional variations in depth-area relations, why were not regional variations in the within/without curves considered in the site-specific PMP study for Cherry Creek? (Tomlinson)

The group did not reach consensus. The NWS will examine a way to verify this assumption.

9. Among storm K-factors were applied to the within storm rainfall values to account for orographic effects, in agreement with the HMR 52 recommendation that additional modification to the distribution of PMP brought about by terrain effects be considered (Section 5.1, p43). However, HMR 52 states that these local modifications should modify or warp the pattern in the direction of major storm patterns that have been observed in the drainage. Does the application of the among storm K-factors modify the pattern in the direction of major storm patterns that have been observed in the drainage? Please provide examples. (Tomlinson)

The group did not reach consensus. The NWS opinion is that any additional study results will have a minimal impact on results and there will be no further examination of this issue at this time.

10. The barrier elevation map in HMR 55A was used to adjust the raster fields of “non-

orographic” values to sea level. Was this map also used for its intended purpose, i.e. moisture depletion? (Tomlinson)

The group agreed this question was answered. HMR 55A PMP values included moisture barrier depletion.

11. The BOSS software package has demonstrated errors in its calculation of within storm isohyetal values (personal communication, Ellen Faulkner, Mead and Hunt Engineering, June, 1999). The software sometimes produces rainfall volumes larger than the PMP for areas smaller than the PMS. Were tests conducted to demonstrate that this error did not occur? (Tomlinson)

No longer applicable according to Dr. Tomlinson.

12. The chronology for the temporal variations were based on hourly percentage contributions from PRHMR 52. Were these variations derived from the same 29 storms used to derive the within/without storm curves in HMR 52? How do they compare to the largest storms which are transpositionable to the Cherry Creek drainage basin? Explicitly, what other chronologies can be used, how would they be derived, and what criteria is used to determine that they are permissible? (Tomlinson)

The group agreed this does not impact the hydrologic modeling of the Probable Maximum Flood (PMF).

13. Paragraph 2 of the introduction states that “ This study also supplements, to a limited extent, NOAA Technical Memorandum, NWS Hydro 45 1/4” What is meant by “limited extent”? (Tomlinson)

The antecedent study applied some of the methodology from Hydro 45 and extended the area. The group agreed this was a satisfactory answer.

14. The last sentence in the same paragraph state that “Most of the statistical relationships developed for HYDRO 45 were not investigated in the present study due to time constraints”. What were the time constraints and what additional statistical relationships would have been performed had the time constraints not been present? (Tomlinson)

This referred to items done in Hydro 45 that were not needed for the (Cherry Creek) antecedent study. The time constraints did not affect the quality of the study. The group agreed this was a satisfactory answer.

15. The region within which storms should have meteorologically homogeneous characteristics with storms that could occur over the Cherry Creek drainage basin is defined on p2 of the study. The eastern most boundary of the region is 105.9 degrees West longitude. In comparing this eastern limit with the 29 storms in deriving the within/without storm curves in HMR 52, there is no overlap. This appears to be stating that any storms east of

105.9 degrees West are not to be considered to have meteorologically homogeneous characteristics with the Cherry Creek drainage basin location. The only Colorado storm used in within/without curves derivation in HMR 52 (Hale, 1935) does not fall within this region. This indicates an inconsistency between this study and the site-specific PMP study. (Tomlinson)

The correct eastern boundary (for the Cherry Creek antecedent study) is 104.3 degrees longitude. The group did not reach consensus. The NWS will examine a way to verify this assumption.

16. *NWS HYDRO 45, dated January 1995, states on page 75, Finding 15 that “By logical deduction and extension, the conclusion is that a reasonable and prudent antecedent precipitation associated with a 3- to 5-day PMP event in the region of study would be 10-20 percent of the PMP within a 31-day period centered on the day of maximum precipitation in the PMP storm for the region of study.” Explicitly what caused the difference between this 10-20% and 32% provided in the Cherry Creek antecedent precipitation study? (Tomlinson)*

USACE will investigate the possibility of revising the antecedent study and its potential impacts.

17. *Often dam regulators use the 100-year event, e.g. rainfall or snowmelt, as the antecedent condition. What is the return frequency of the 32% PMP event for the Cherry Creek drainage basin? If the PMP is seven times the 100-year rainfall, that should make the antecedent rainfall 32% of seven or 2.24 times the 100-year rainfall values. How does this compare to the antecedent rainfall used for other Corp Projects, in particular Cochite and Elephant Butte in New Mexico? (Tomlinson)*

The USACE guidelines state an antecedent flood of 50% of the Probable Maximum Flood (PMF) with a 5-day drawdown or a half²-full flood control pool (which ever is more appropriate) is used unless a site specific antecedent study provides other information. Question was withdrawn.

18. *Where should the boundary for orographic effects be placed? (Hammer)*

This question will not impact the site specific Cherry Creek PMP study. The issue is whether this boundary can be more accurately placed with additional study.

19. *Determination of the average percentage of hail vs. the percentage of rainfall in a major storm event should be done. Hail is almost always present in a major event. Extracting the hail values will reduce rainfall values and resulting runoff rates. (Greenwood Village Meeting)*

The group agreed that hail has no consequence on the final precipitation values and final

² USACE reviewed its Engineer Regulation following the meeting. The Regulation states full flood control pool rather than half-full flood control pool.

volume of runoff in a PMP event.

20. *The values associated with the maximum one hour rainfall should be re-evaluated. Questions remain on the validity of the measurement of 11 inches attributed to the first hour of the storm based on water measured in a horse trough, especially considering that it appears that rainfall on the order of a couple of inches fell over the region during the previous evening. 1935 Cherry Creek (Hale) storm. (Tomlinson)*

The group consensus was this is based on best available data.

21. *The location of the storm center with respect to the Palmer Ridge, i.e. just downwind of the ridge, is consistent with other extreme rainfall events (e.g. Plum Creek, 1965) with the associated storm isohyetal patterns showing sharp decreases beyond about 15 miles downwind, i.e. to the north and northwest. If the Palmer Ridge does provide a significant or even a dominant influence on the position of the storm center, transpositioning constraints may be appropriate in positioning the design storm over the watershed when computing the PMF. (Tomlinson)*

The group agrees with the NWS that there are topographic effects on the north and south sides of the Palmer Ridge.

22. *Other large rainfall storm centers along the Front Range, e.g. west of Denver, are located over the foothills or even further up the east slope of the Rockies, suggesting a “rainshadow” for extreme storm rainfall centers over portions of the region between the Palmer Ridge and the foothills to the northwest. (Tomlinson)*

The group agrees with the NWS that there are topographic effects on the north and south sides of the Palmer Ridge.

23. *The maximization procedure used in HMR 55A used a storm representative dew point value which was computed using observations taken 560 miles to the southeast. Possibly re-analysis could identify observational data closer to the rainfall event which would more accurately represent the moist mass which provided the available moisture for the storm dynamics to convert to rain on the ground. (Tomlinson)*

The NWS will examine the data and determine its likely effect on HMR 55A and on the Cherry Creek site specific PMP.

24. *The accepted depth-area-duration values used together with the maximization factor of 163% produced maximized rainfall values which were not consistent with and significantly larger than maximized values derived from analyses of other large storm events along the Front Range. To provide a more consistent analysis, the values were undercut (decreased) by about 15% by the authors of HMR 55A. Current PMP evaluations impose an upper limit of 150% when applying maximization factors to storm D-A-D's. Possibly an updated dew point analysis as discussed in 23 above would provide an improvement for the maximization factor. (Tomlinson)*

The NWS will examine the data and determine its likely effect on HMR 55A and on the Cherry Creek site specific PMP.

25. *The Bureau of Reclamation re-examined the Cherry Creek storm in 1985 and produced an updated depth-area-duration analysis which contained slightly lower values. However, the rainfall values (see item 11 above) and mass curves from previous studies were not evaluated for reliability and internal consistency. (Tomlinson)*

The group consensus was this is based on best available data.

26. *The NOAA Hydrometeorology Office completed a site-specific PMP study for the Cherry Creek drainage basin for the Corps of Engineers in July, 1995. They basically extended the non-orographic procedures provided in HMR 52 westward to compute the design storm for the basin. Critical centering of the design storm assumes no orographic influence of the Palmer Ridge. This assumption is questioned by Dr Jarrett of the USGS in Denver; Mr Loren Crow, a private Certified Consulting Meteorologist in Denver; and Mr Nolan Doeskins of the Colorado Climate Center as well as myself. Although quantification of the influence of topography on this and other Front Range storms has yet to be determined, it provides a significant open issue for PMP analyses along the Front Range. (Tomlinson)*

The group agrees with the NWS that there are topographic effects on the north and south sides of the Palmer Ridge.

27. *Following extensive discussions intended to justify using HMR 52 because the topography of the Cherry Creek Drainage is not significant, the PMP amounts are increased up to 14% because of the topography based on 100-year precipitation climatology. If in fact this is an acceptable procedure, it needs to be demonstrated that the 100-year precipitation is based on rainfall not snowfall, a significant consideration in Colorado. (Tomlinson)*

The 100-year precipitation study (NOAA Atlas 2) was not updated because it was beyond the resources of the NWS. The group consensus was the study (NOAA Atlas 2) needs to be updated. The impact is unknown until the update is done.

28. *Use of orographic among-storm factors to adjust non-orographic within-storm factors (a technical issue which could significantly increase the rainfall volume). (Tomlinson)*

The group did not reach consensus. The NWS opinion is that any additional study results will have a minimal impact on results and there will be no further examination of this issue at this time.

29. *PMP values, both generalized and site-specific, are derived from analyses of the most significant rainfall events observed within geographically and climatologically similar regions. These observed rainfall amounts are adjusted using standardized procedures to provide "maximized" rainfall amounts, i.e. the storm rainfall is theoretically increased to its*

“maximum value. These theoretical rainfall totals are sometime increased slightly to provide continuity with other maximized rainfall totals from other storms. These maximized rainfall amounts provide the basis for determining the PMP values for the basin being studied. The Cherry Creek Drainage has had one of these extreme rainfall events occur within the basin in 1935. The maximization procedure increases the rainfall amount by 22% (HMR 51) to provide a basis for estimating the PMP for the basin. The NWS site-specific PMP study provides PMP amounts which exceed the “maximized” 1935 rainfall by over 60%, a very large increase over the maximized extreme storm value. (Tomlinson)

The 22% and 60% values (in the comment) are erroneous, but the concept of extreme envelopment will be examined by the NWS.

30. *Since PMP values are the “theoretical greatest”, there is no objective way to evaluate if the rainfall amounts are “correct”. However, the PMP values are often compared to the 100-year precipitation amounts and are generally expected to be larger by a factor between two and three. The range in values in HMR publications in the western US varies from 1.4 to 7.5. According to the NWS study, the “maximum point values ¼ from this study exceed the largest 100-year return period precipitation in the Cherry Creek Drainage by roughly seven times.” This places the ratio of the Cherry Creek PMP values to the 100-year precipitation values is in the extreme high range for the western US. (Tomlinson)*

Other comparisons (NWS 25 Report) show the 6 to 1 ratio for the PMP to 100-year rainfall in Colorado is not an unusual occurrence. The group reached consensus on this.

31. *Techniques from two separate Hydrometeorological Reports (HMR’s) i.e. HMR 52 and HMR 55A are combined without demonstrating consistency among the assumptions and data bases used in the two documents. (Tomlinson)*

The group did not reach consensus. The NWS will examine a way to verify this assumption.

32. *The HMR 52 techniques were developed for and intended for use east of the orographic separation line (OSL) in Colorado (HMR 55A), i.e. over the eastern plains of Colorado and central plains of the US. The Cherry Creek Drainage lies almost entirely west of the OSL. HMR 55A states that additional study is required before HMR 52 techniques as developed for non-orographic storms can be applied reliably to the Cherry Creek Drainage. The discussion in the study does not provide this addition study. (Tomlinson)*

The group did not reach consensus. The NWS will examine a way to verify this assumption

33. *What is the stratification of rain versus snow for the events selected for the antecedent study. What are the impacts of snow events (if any) on the study. (Henz)*

NWS will examine and report back its findings.

34. *Domain for storms used in Antecedent Storm Study is not the same domain for storms*

used in HMR 52. (Tomlinson)

The NWS will examine the issue and will respond to the concern. The NWS will examine the issue and will respond to the concern. The NWS will examine the issue and will respond to the concern.

35. The data from the Antecedent Storm Study is a spurious correlation of data. (Schaffer via Tomlinson)

The NWS will examine the issue and will respond to the concern.

36. Propose analyzing additional storms identified by the State Climatologist to compare with the within/without curves in HMR 52.

The group did not reach consensus. The NWS will examine the issue and will respond to the concern.

SUMMARY COMMENTS

The meeting today was a thorough review and helps the non-federal interests understand the PMP study.

The group agreed that a single dissenting opinion left the group without consensus. On unresolved issues, the members of the group were divided on their concurrence with the NWS approach.

The NWS agreed to reexamine its study in light of several specific issues raised by the group, but the NWS does not expect the reexamination to have a significant impact on the PMP estimate. Some participants feel the reexamination could result in significant changes to the PMP estimates.

NWS PMP procedure is the only acceptable procedure for the Corps of Engineers.

The Corps/NWS may request clarifying information from the authors of unresolved issues.